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Central Forecasting Technical Note No.20

Results from a parallel trial to investigate the use of satellite cloud-motion winds

By

A.M.Radford

July 1994

Central Forecasting Division
Meteorological Office
London Road
Bracknell
Berkshire
RG12 2SZ

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1. Introduction

Cloud-motion winds (CMWs) are derived by tracking clouds in sequences of images from geostationary satellites. These CMWs are then disseminated on the GTS in SATOB code.

There are currently 4 satellites from which CMWs are produced, namely METEOSAT-5 (operated by Europe and located at 0°E), GOES-7 (United States -140°W), GMS-4 (Japan - 140°E) and INSAT-2A (India - 74°E). India produces winds for 00 and 12 UTC only, but the remaining satellite operators produce CMWs four times a day, usually valid within 1 hour of the main synoptic hours.

The quality of the product varies from satellite to satellite because of differences in ground processing techniques, particularly that of cloud height assignment. This has led to the use of a 'permanent rejection list' for SATOB wind observations within the observation processing, whereby restrictions are placed on the data that are actually used by the data assimilation. These restrictions have been arrived at by using: (a) standard data monitoring techniques (e.g. comparison with model background fields) and, (b) knowledge of the methods used by the various satellite data producers.

The restrictions currently in place are:

- no INSAT winds are used;
- no upper-level GMS winds are used outside the tropics (20°N - 20°S);
- no upper-level METEOSAT or GOES winds *over land* are used outside the tropics.

Recent monitoring results, both from CF Division (Leighton, 1994) and ECMWF (Kelly, *pers. comm.*), suggest that the permanent rejection list for SATOBs needs to be changed. There now seems to be little difference in quality, as measured by O-B statistics, between the 3 major satellites - METEOSAT, GOES and GMS. ECMWF is planning to include all 3 datasets in the near future. Moreover a 3-month study performed by ECMWF suggests that the quality of upper-level winds over land and sea is similar, but low-level winds are poorer over land (although in reality the number of low-level SATOBs produced over land is small). It is therefore proposed that we change our rejection list by:

a.	adding	extra-tropical high-level	GOES/METEOSAT	over land;
b.	adding	extra-tropical high-level	GMS	over land & sea;
c.	removing	extra-tropical low-level	GMS/GOES/METEOSAT	over land.

The restrictions on SATOB data are therefore rationalised:

- no INSAT winds are used;
- no low-level METEOSAT, GOES or GMS winds are used over land outside the tropics (20°N - 20°S).

2. The Parallel Trial

The Parallel Suite was used to assess the impact of the proposed changes on the global model analysis and forecast. The experiment ran from 18-31 May 1994, with a 5-day forecast being run once a day from the 12 UTC analysis. An observation processing database (OPD) was generated from each data assimilation cycle. The verification statistics produced used observations (SYNOPs and radiosondes) and analyses as standards of comparison, and were generated at 24-hour intervals into each forecast.

Because of the inherent problems in comparing the verification of the forecasts against their own analyses, these results are not presented here.

3. Verification

3.1 OPD comparison

The OPD provides information on O-B (observation minus background) differences. These statistics can therefore be interpreted as a verification of the 6-hour forecast. In Table 1, the root mean square vector wind (rmsvw) O-B differences are given for all AIREPs reporting in the range 100 to 400 hPa, and for upper-air data (radiosondes and pilot balloons) at the standard levels of 250hPa, 500hPa, 700hPa and 850hPa. The statistics have further been divided into three areas: Northern Hemisphere (90°N-30°N), Tropics (30°N-30°S) and Southern Hemisphere (30°S-90°S).

	NH		Tropics		SH	
Level	Oper	Trial	Oper	Trial	Oper	Trial
AIREPs	6.93	6.93	***5.89***	5.93	7.96	***7.95***
250 hPa	***6.34***	6.36	6.54	6.54	8.79	8.79
500 hPa	4.59	4.59	***4.75***	4.76	***7.16***	7.17
700 hPa	***4.14***	4.15	4.62	4.62	6.21	***6.17***
850 hPa	4.29	4.29	4.43	4.43	6.45	***6.42***

Table 1: Root mean square vector wind O-B differences for AIREPs and upper-air data at selected levels for three areas (units are ms^{-1}). Lower (better) values are highlighted in ***bold***.

The natural distribution of observations implies that the comparisons against aircraft and upper-air data should be indicative of the model's performance over sea and land respectively. Bearing in mind that the changes being tested involve the distinction between land and sea, this factor could be useful in assessing the impact of those changes. However, Table 1 shows that the differences between the trial and operational forecasts are very small - none is greater than 0.7%. It is very difficult to detect a signal, except possibly in the southern hemisphere, where 3 of the 5 scores favour the trial.

O-B statistics were also calculated for SATOB winds themselves, but are not shown here. As would be expected, the rmsvw differences for the upper level winds are noticeably lower (by more than 3%) in the trial than in the operational forecasts.

3.2 Verification against observations

Following the procedure that has been used in reporting the results from previous parallel trials by FR Division (e.g. Bell, 1994), the verification scores are presented as a percentage change in root mean square (rms) error. This is defined as

100% * [oper. score - trial score] / [oper. score]

so that a negative value indicates a poorer performance in the trial.

The results are presented for the following variables:

- height at 850 hPa, 500 hPa and 250 hPa
- wind at 850 hPa, 500 hPa and 250 hPa
- temperature at 850 hPa, 500 hPa and 250 hPa
- pressure at mean sea-level (pmsl)

for three areas:

- northern hemisphere - 90°N to 30°N - table 2
- tropics - 30°N to 30°S - table 3
- southern hemisphere - 30°S to 90°S - table 4

There are certain limitations in the verification system, the most important one being that all scores, apart from pmsl, are calculated by comparing with radiosonde observations, and these are (a) mainly over continental areas, and (b) poorly distributed in the southern hemisphere. Another factor to bear in mind is that SATOBs are only produced within 55° latitude of the equator, whereas the verification for northern and southern hemispheres includes observations outside this area.

	T+0	T+24	T+48	T+72	T+96	T+120
H850	***1.1***	***0.5***	0.1	0.3	0.4	0.2
H500	0.0	0.2	-0.2	0.2	0.3	-0.2
H250	0.4	-0.2	0.2	***0.5***	0.0	-0.2
T850	-0.2	0.0	0.1	0.2	0.4	0.4
T500	-0.2	-0.1	0.3	***0.5***	-0.2	-0.3
T250	-0.2	-0.1	-0.2	0.1	***-0.7***	-0.3
W850	-0.1	0.1	0.3	-0.1	0.3	0.1
W500	0.1	0.1	0.2	0.2	0.0	0.1
W250	-0.2	-0.1	0.1	0.2	0.2	-0.2
PMSL	-0.2	-0.3	-0.1	0.0	0.1	0.4

Table 2: Percentage change in rms verification score for northern hemisphere (see text for details). Changes of at least 0.5% are highlighted in ***bold***.

For the northern hemisphere (table 2) the impact is marginal. Only 5 scores are different by 0.5% or more, and 4 of these are in favour of the trial. The most noticeable is the 1.1% improvement in the 850hPa height verification of the analysis. This suggests that the rejection of low-level winds over land has had a positive effect, although the removal of

one data source (SATOBs) from the assimilation will automatically improve the verification against another (sondes) at T+0. It is also interesting to note that greater impact is seen in the verification scores for height and temperature than for wind, suggesting that the WINDBAL algorithm (Bell, 1994) is playing a part here.

	T+0	T+24	T+48	T+72	T+96	T+120
H850	-0.1	***-1.3***	-0.1	***0.9***	***0.7***	-0.1
H500	0.0	0.1	-0.1	***1.2***	***1.0***	***0.9***
H250	0.3	-0.1	0.2	0.2	***0.7***	***0.7***
T850	-0.4	-0.2	***-0.9***	***0.5***	0.4	0.3
T500	0.3	***-0.5***	***-0.6***	***-0.6***	***0.6***	***0.5***
T250	***0.5***	0.0	0.3	0.0	***-0.6***	***-1.1***
W850	0.2	-0.1	0.1	-0.3	0.0	0.1
W500	-0.1	-0.2	-0.1	***-0.5***	-0.1	-0.3
W250	0.3	-0.4	-0.2	0.2	0.1	***-1.8***
PMSL	0.0	***-0.5***	-0.3	0.2	-0.2	***-0.8***

Table 3: Percentage change in rms verification score for tropics (see text for details). Changes of at least 0.5% are highlighted in ***bold***.

Bearing in mind that no change has been made to the use of SATOBs in the tropics it is perhaps surprising that the impact in this area (table 3) is larger than in the northern hemisphere. However, part of this discrepancy can be accounted for by the difference in definition of 'tropics' between the observation processing (20°N - 20°S) and the verification (30°N - 30°S). There is no apparent signal in the scores, with the distribution of positive and negative values being almost identical. The largest positive impact is in the latter stages of the height forecasts. The largest negative impact is for 250hPa winds at T+120, although the other changes in the wind scores are no worse than -0.5%.

	T+0	T+24	T+48	T+72	T+96	T+120
H850	0.2	0.3	***1.2***	***1.2***	***0.7***	-0.1
H500	0.2	-0.3	-0.1	***0.9***	***1.0***	***1.0***
H250	***0.6***	-0.2	0.2	***0.9***	***0.9***	***1.2***
T850	0.1	0.1	-0.1	0.1	***1.5***	***2.7***
T500	***-1.5***	0.2	-0.1	0.3	***1.6***	***0.5***
T250	***-0.6***	-0.1	0.2	***-0.5***	***1.1***	-0.1
W850	0.0	0.0	-0.1	-0.4	***0.7***	***1.1***
W500	***-0.6***	0.3	-0.1	0.2	0.0	***0.6***
W250	-0.2	***-1.3***	***-1.8***	0.0	***-0.6***	***-1.4***
PMSL	-0.1	***1.0***	***0.5***	***0.9***	***0.5***	0.1

Table 4: Percentage change in rms verification score for southern hemisphere (see text for details). Changes of at least 0.5% are highlighted in ***bold***.

The largest impact is seen in the southern hemisphere (table 4), particularly from T+72 onwards in the verification of height and temperature. The largest improvement is 2.7% in the scores for 850hPa temperature at T+120. Pmsl verification is also improved, but 250hPa winds are worse.

Referring back to section 1, the changes that have been made to the SATOB usage can be divided into those over land and those over sea. Bearing in mind that there is a certain amount of data redundancy over the northern hemisphere land areas, one could anticipate that the largest impact would come from the addition of high-level GMS data over the western Pacific. The impact of these data might be expected to affect the flow over North America in the 2-3 day range and over Europe at days 4-5.

Table 5 shows the verification scores for 'Area 2', which covers a large part of North America, the north Atlantic and most of western Europe. The impacts here are much larger than for the northern hemisphere as a whole, particularly at T+120. In fact it is generally true that the scores improve toward the end of the forecast period - at T+96 and T+120 all the differences are non-negative. The tentative conclusion, therefore, is that the high-level GMS data are indeed having a positive impact on the forecast.

	T+0	T+24	T+48	T+72	T+96	T+120
H850	***-0.8***	-0.1	-0.4	***-0.6***	0.2	***0.9***
H500	***-0.6***	0.0	0.3	0.0	0.1	***1.0***
H250	***1.4***	***0.9***	0.2	***0.6***	0.0	***0.9***
T850	0.0	0.0	0.0	0.4	0.3	***0.7***
T500	***1.2***	***0.5***	0.0	0.1	0.4	***0.5***
T250	***0.6***	0.1	***-0.7***	0.0	0.0	***0.6***
W850	0.1	0.0	-0.2	0.1	0.4	***1.0***
W500	0.3	-0.3	-0.2	0.1	0.0	***0.5***
W250	0.0	0.0	0.0	0.4	0.4	***0.7***
PMSL	0.0	0.0	***-0.6***	***-0.9***	0.2	***0.7***

Table 5: Percentage change in rms verification score for Area 2 (see text for details). Changes of at least 0.5% are highlighted in ***bold***.

3.3 Subjective comparison

Charts were produced from each forecast showing the differences between the operational and the trial runs for a variety of parameters. Many of the analysis differences diminished early in the forecast period, although by day 5 some large changes had again developed. However, these tended to be dwarfed by the forecast errors at this range. The greatest differences were generally found over the southern hemispheric oceans, making them difficult to verify.

Two of the largest analysis differences noted in the northern hemisphere were over north Africa. These have been examined in detail, using the workstation facility OPDPLOT (developed by B.Ingleby, FR Division), and are discussed below.

(a) 12UTC 19 May 1994

Figures 1 and 2 show the 250hPa isotach analyses (for the operational and trial runs respectively) for 12UTC 19 May 1994. A significant difference can be seen over north Africa, where the sub-tropical jet core of over 60Kt centred near 28°N 10°E in the operational analysis has been re-analysed further west and slightly stronger in the trial.

Figure 3 shows all wind observations available to the operational analysis in the layer 350 to 150 hPa between 09UTC and 15UTC. The observations labelled '000005' represent SATOBs from METEOSAT, while the remaining observations are from 6 radiosondes and 1 pilot balloon ascent. Note that the northern limit of the SATOB data is 20°N corresponding to the current operational use of high-level SATOBs over land.

Figure 4 is equivalent to Figure 3 but for the trial analysis. Ten more SATOBs (north of 20°N) are now available for the analysis. The group of 3 observations of 55-60Kt near 22°N 2°W appear to have had the effect of repositioning the jet core noted in figure 2. These data are consistent with the radiosonde observation from station 60630, suggesting that the trial version is probably a better analysis of the wind field.

(b) 12UTC 21 May 1994

Figures 5 and 6 show the 250hPa isotach analyses (for the operational and trial runs respectively) two days later at 12UTC 21 May 1994. A significant difference can once again be seen over north Africa, where the sub-tropical jet core of 57Kt near 25°N 20°E in the operational analysis has been reduced to 46Kt in the trial.

Figure 7 shows all wind observations available to the operational analysis in the layer 350 to 150 hPa between 09UTC and 15UTC. On this occasion there are 3 SATOBs, 4 radiosondes, and 2 aircraft reports from the same aircraft (SWR262).

Figure 8 is equivalent to Figure 7 but for the trial analysis. Sixteen more SATOBs (north of 20°N) are now available for the analysis. Clearly the 'new' data are more in agreement with the radiosonde 60680 than with the southernmost AIREP SWR262 and so the wind analysis in the trial is much lighter in this area. The evidence for improvement is less clear-cut than in the previous case, but the internal consistency of the SATOB data and the support of the radiosonde throws doubt on the quality of the aircraft report. Efforts to check further on the track of the aircraft proved fruitless as the only 2 observations received are those plotted.

4. Conclusions & Recommendations

The trial has shown that the proposed rationalisation of the use of satellite CMWs has only a small and marginal effect on the analyses and forecasts. Least impact is seen in the northern hemisphere, while the greatest (mostly positive) effects are in the southern hemisphere, although the limitations of the verification in this area must be recognised. There is also the general point that the introduction of another data source (high-level SATOBs) into the analysis will automatically degrade the verification against radiosondes, particularly in the very early stages of the forecast.

Verification figures over Area 2 are improved, suggesting that the inclusion of high-level GMS data over the western Pacific are having a positive impact downstream in the medium range. The two cases examined in detail subjectively suggest that the analyses are improved.

It is recommended that the proposed changes are made operational.

5. Acknowledgements

Thanks go to J.Heming and B.Little (CF5) for setting up the experiment, and C.Hynes (Parallel Suite Manager) for scheduling and running it. S.Bell (FR) provided the verification software and some useful comments on the draft version; B.Ingleby (FR) developed the OPDPLOT software.

6. References

Bell, R.S., 1994: "An operational trial to validate the use of Balanced Mass Increments derived from Assimilation Wind Increments." *Forecasting Research Technical Report No.88, March 1994.*

Leighton, J.R., 1994: "Monitoring Statistics for SATEMs and SATOBs: December 1993 - February 1994." *Central Forecasting Monitoring Note No.19, March 1994.*

List of Figures

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4. Trial run - all available wind observations in the layer 350 to 150 hPa between 09UTC and 15UTC 19 May 1994.
5. Operational run - 250hPa isotach analysis for 12UTC 21 May 1994.
6. Trial run - 250hPa isotach analysis for 12UTC 21 May 1994.
7. Operational run - all available wind observations in the layer 350 to 150 hPa between 09UTC and 15UTC 21 May 1994.
8. Trial run - all available wind observations in the layer 350 to 150 hPa between 09UTC and 15UTC 21 May 1994.

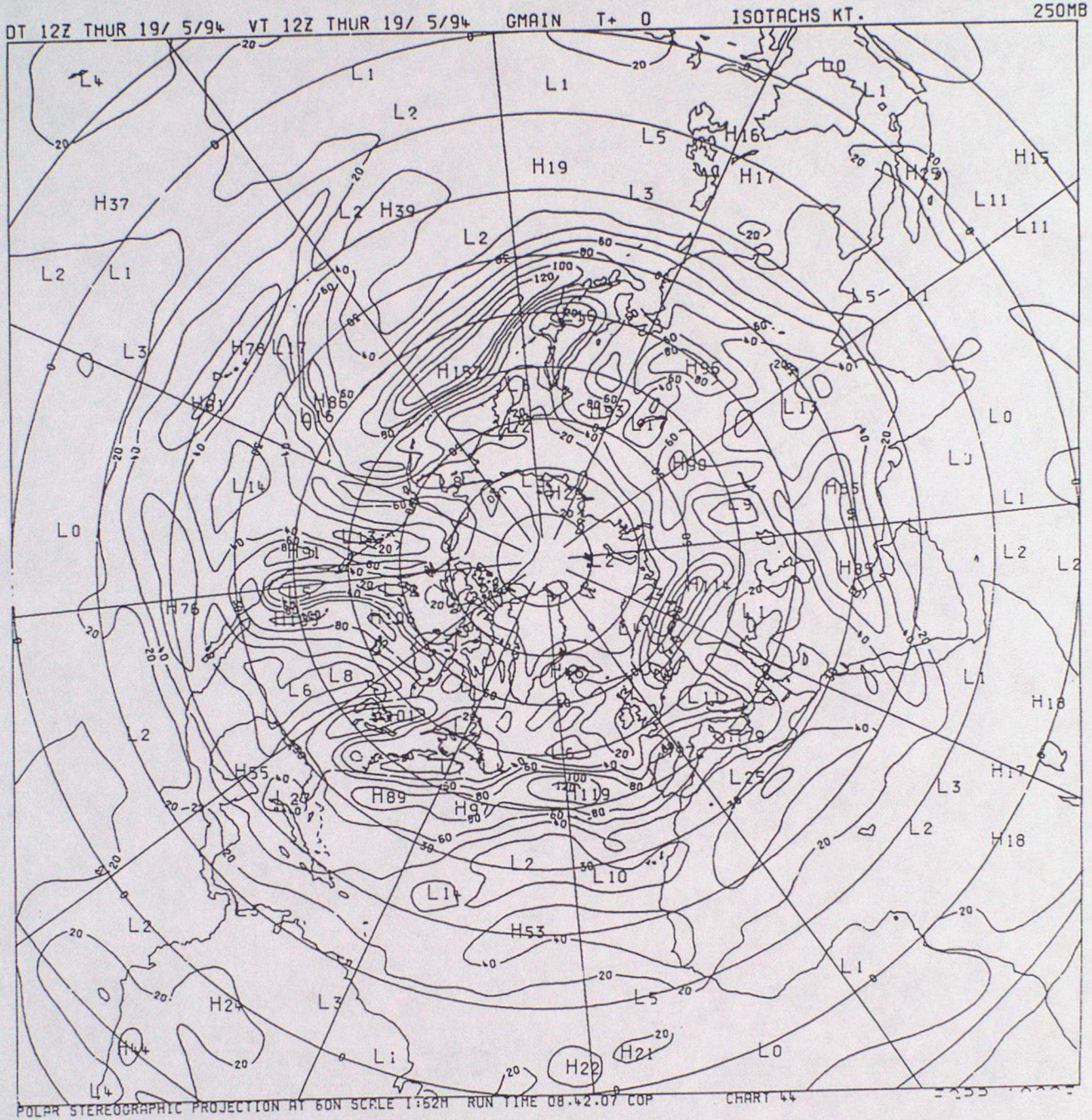
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Figure 1

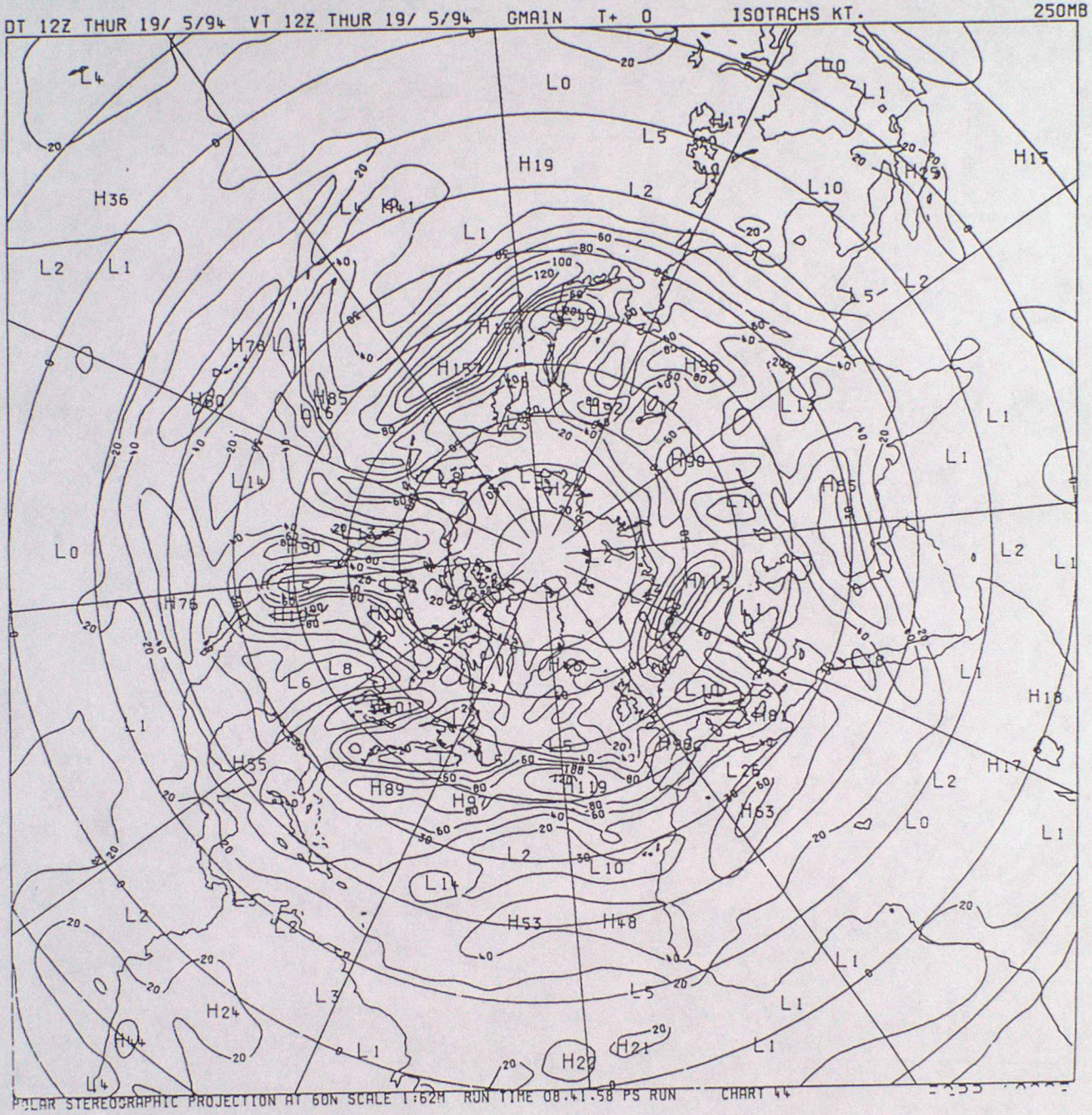
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Figure 2

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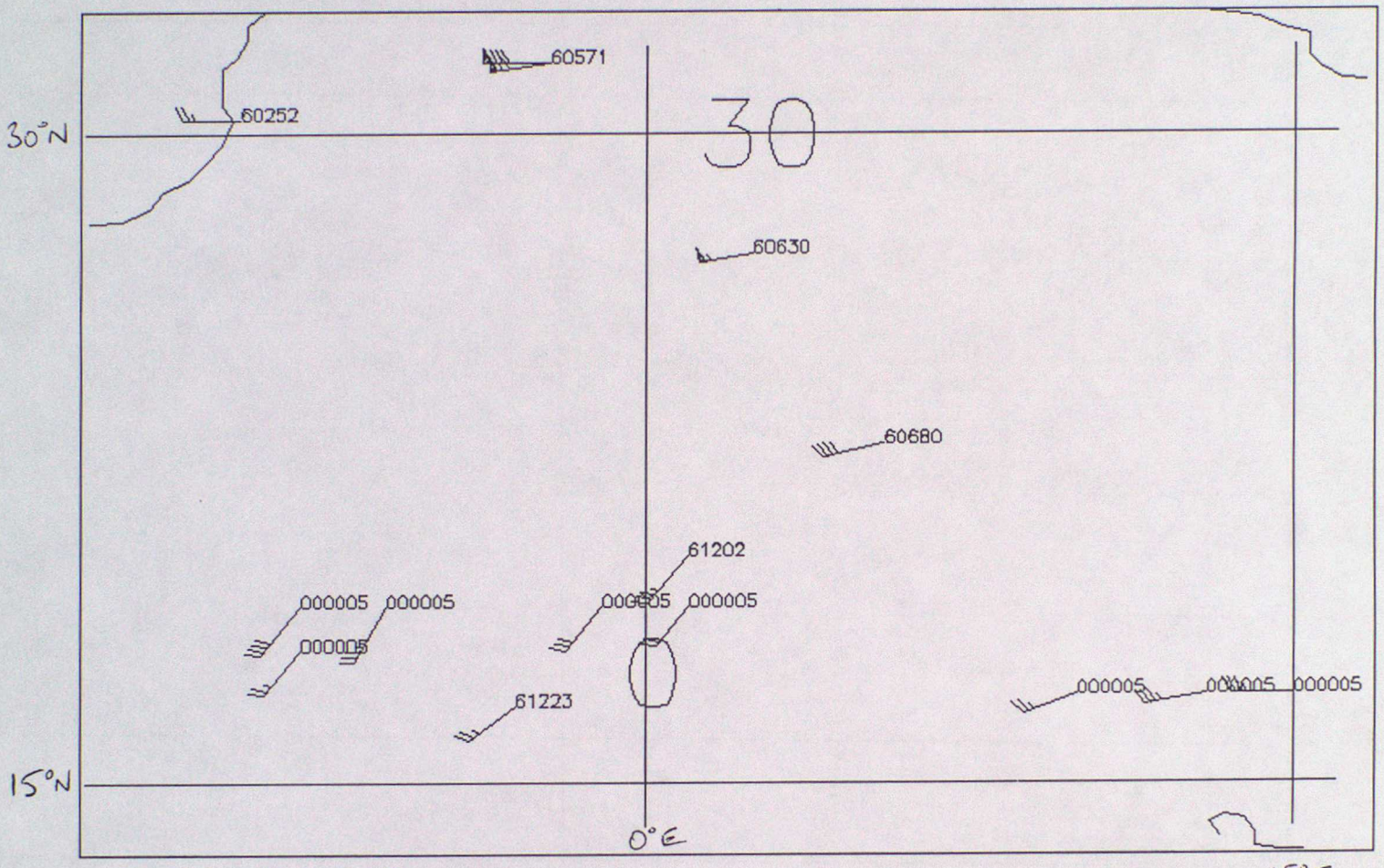

51 OBS 15 PLOTTED

0 B BOGUS	6 R TEMP	1 P PILOT	0 U TSHIP	0 T SATEM
0 G GL/S12	0 A AIREP	0 M AMDAR	0 C ACARS	8 S SATOB

Figure 3

User : cfra Date : Fri. 10 June, 1994 10:18:19 AM

OPD OBSERVATIONS 350.0 MB TO 150.0 MB. SAMPLE
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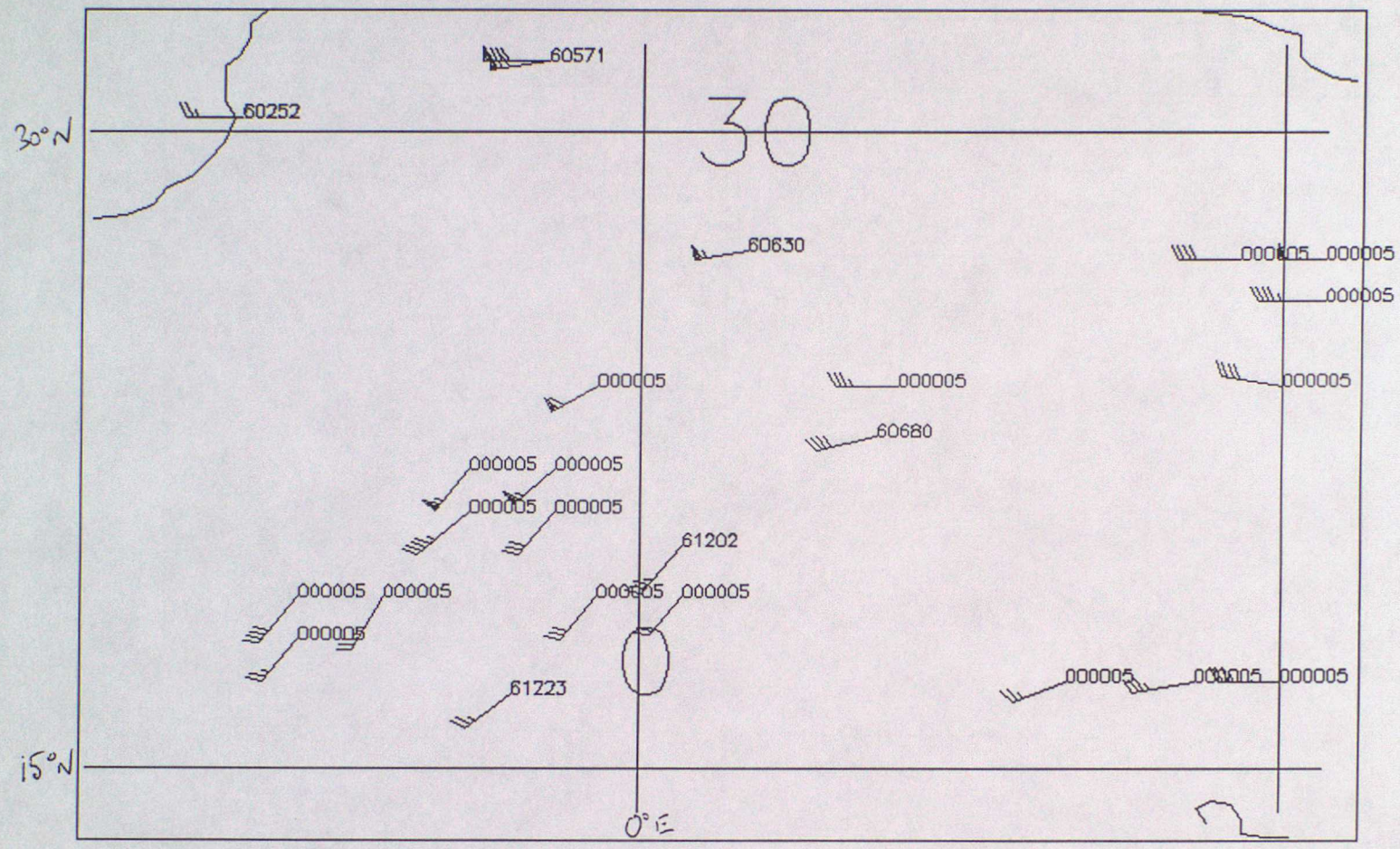

51 OBS 25 PLOTTED

0 B BOGUS	6 R TEMP	1 P PILOT	0 U TSHIP	0 T SATEM
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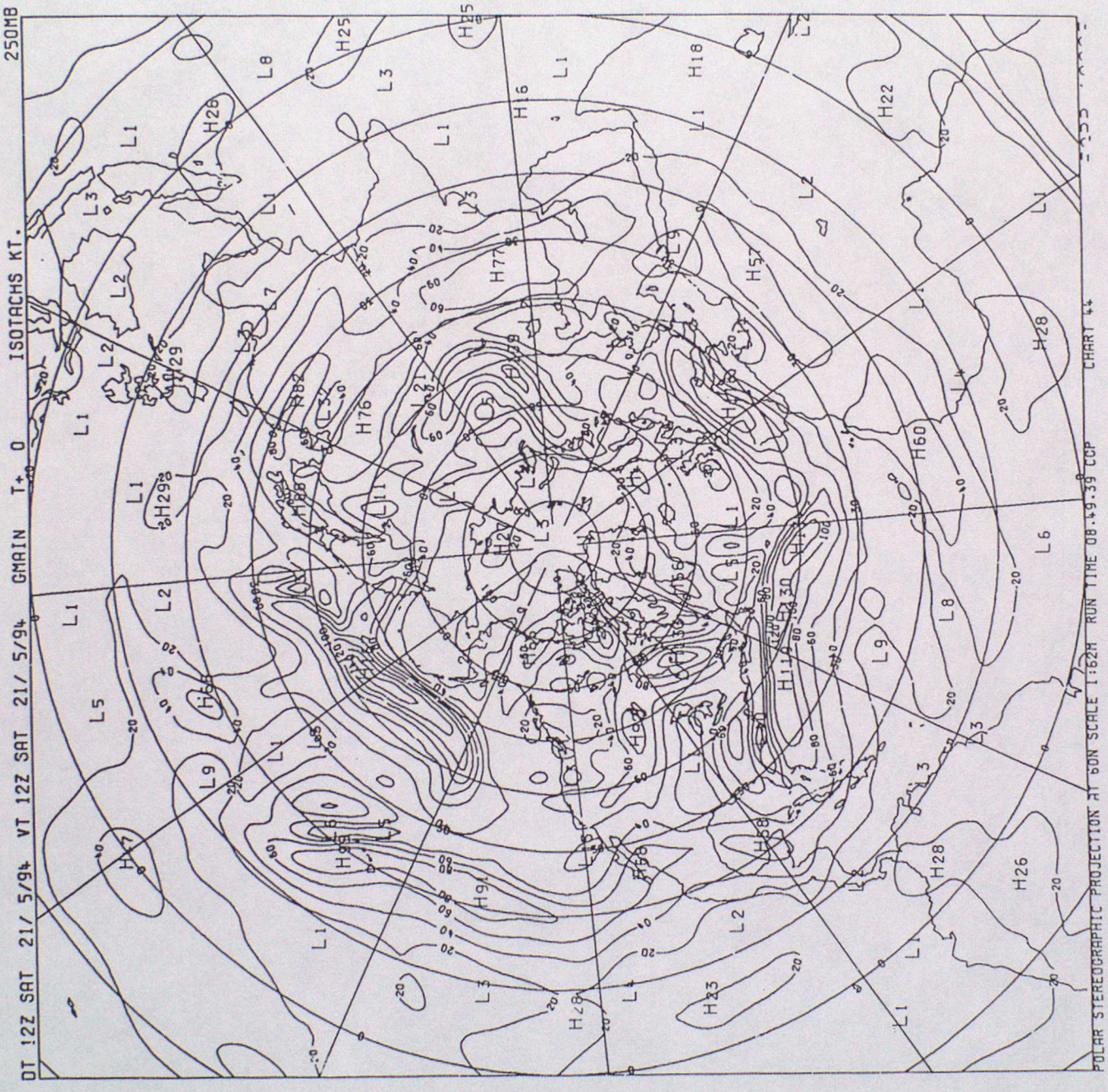
Figure 4

Figure 5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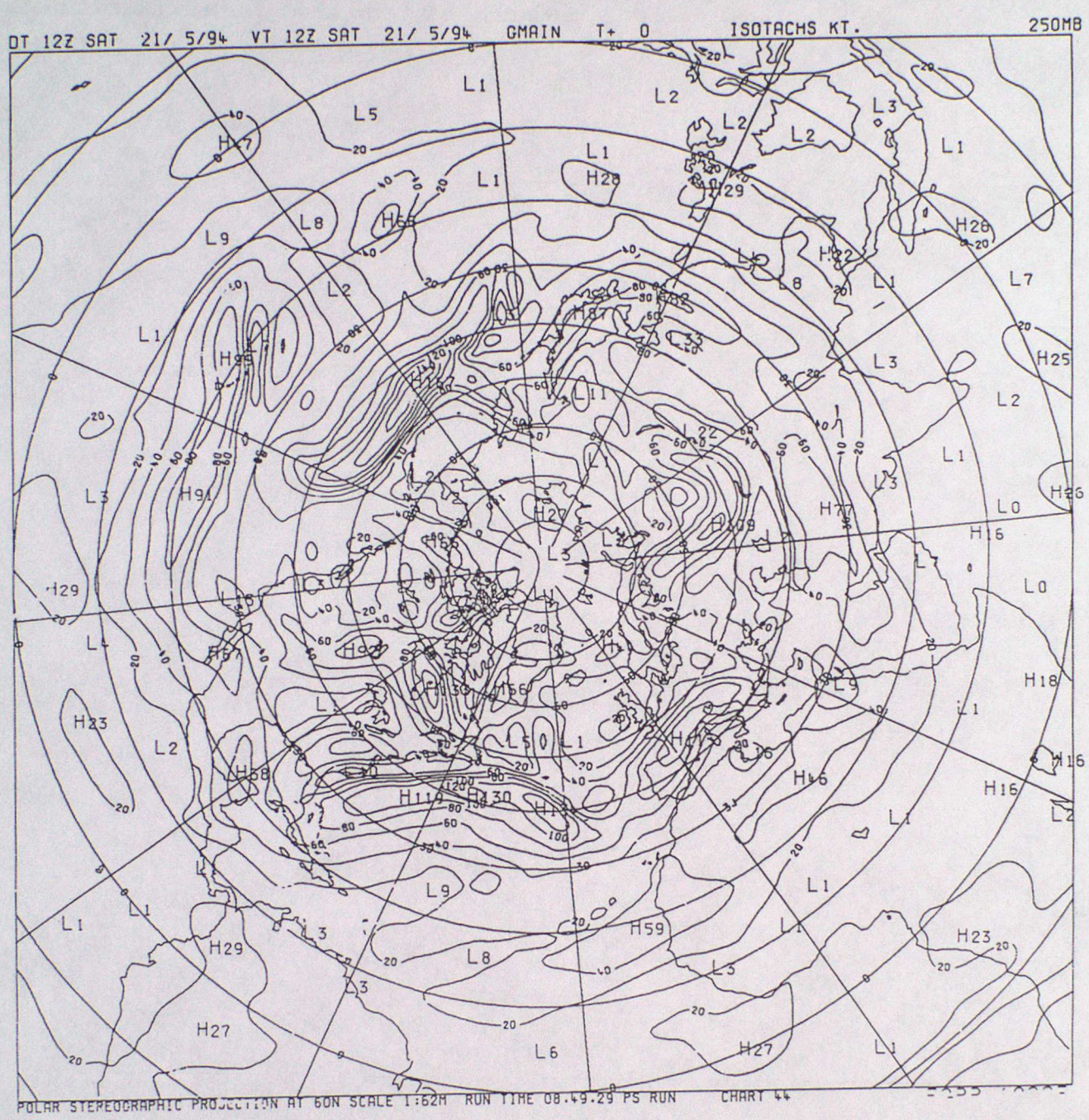
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Figure 6

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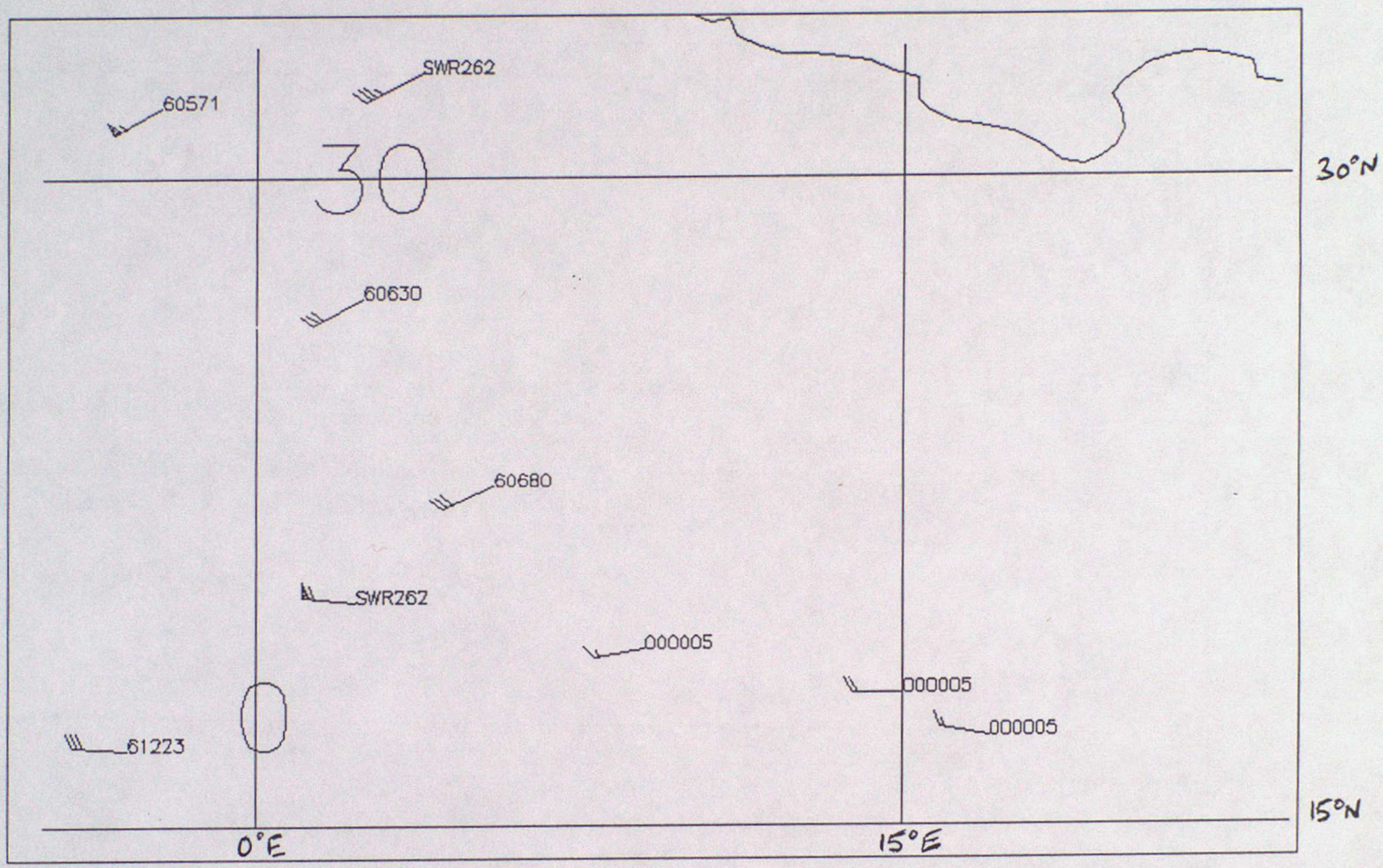

46 OBS 9 PLOTTED

0 B BOGUS	4 R TEMP	0 P PILOT	0 U TSHIP	0 T SATEM
0 G GL/S12	2 A AIREP	0 M AMDAR	0 C ACARS	3 S SATOB

Figure 7

User : cfra Date : Fri. 10 June, 1994 10:25:51 AM

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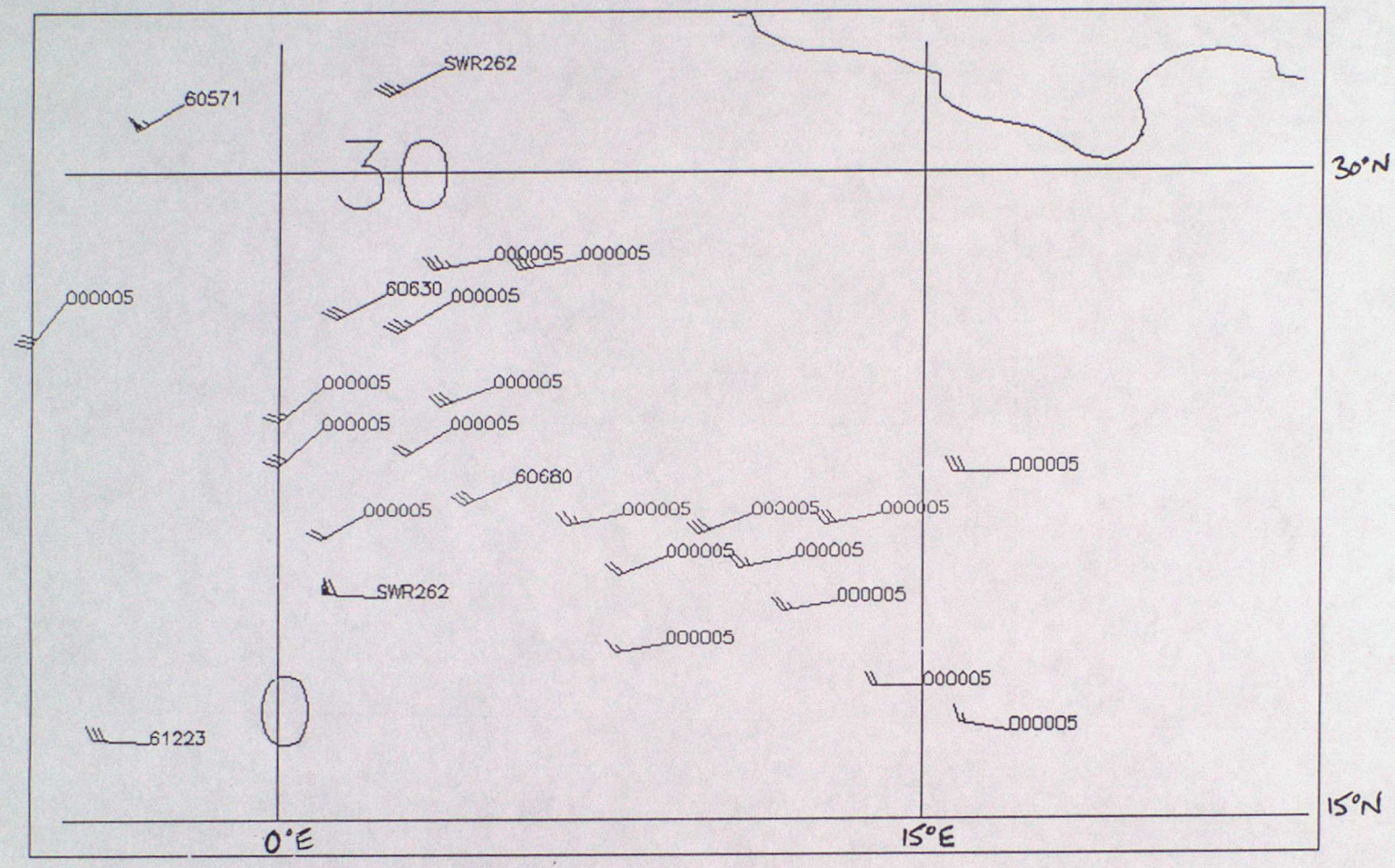

46 OBS 25 PLOTTED

0 B BOGUS	4 R TEMP	0 P PILOT	0 U TSHIP	0 T SATEM
0 G GL/S12	2 A AIREP	0 M AMDAR	0 C ACARS	19 S SATOB

Figure 8

CENTRAL FORECASTING TECHNICAL NOTE

NUMBER	TITLE	AUTHOR	DATE
2	A trial of a scheme to correct the analysed position of tropical cyclones in the operational coarse mesh model.	M. Carter	1988
3	The impact of data on fine mesh forecasts for the storm of January 25 1990.	J. T. Heming	1990
4	Trial of the impact of bogus data in the fine mesh model.	J. T. Heming	1990
5	A guide to numerical weather prediction models and their output.	C. D. Hall	1991
6	Results of the trial of the scheme to reposition features in a model analysis by use of bogus data.	J. T. Heming	1992
7	Operational forecasts of tropical cyclone formation in the western north pacific in 1991.	C. D. Hall	1992
8	Aviation climatology derived from the opeational model. May 1983 - May 1991	P. M. Grimes	1992
9	Effectivness of grib packing for wafs	H. H. Ross P. J. Smith S. D. Turner	1993
10	Investigation into the impact of North Atlantic tempships on the forecasts of U.K. Meteorological office's global & Limited area models	J. T. Heming A. M. Radford	1993
11	User documentation for the Frontier program.	P. Sinclair	1992
12	A trial of the impact of intervention in the Global Model.	J. T. Heming	1993
13	On the use of gridded binary code in producing aviation forecast bulletins	P. J. Smith S. D. Turner	1987 1993
14	The use of gridded binary code in producing products from Bracknell for international exchange in FM92-IX GRIB	P. J. Smith S. D. turner (Edition 1).	1993
15	Analysis of tropical cyclone forecast errors	S. Coulter	1994
16	Monitoring wind observations from the Capel Dewi MST Radar.	A. M. Radford	1994
17	Report on forecasting the probability of NO_2 air quality events using model output statistics.	C. Strudwicke	1994

CENTRAL FORECASTING TECHNICAL NOTE

NUMBER	TITLE	AUTHOR	DATE
18	Examination of bogus and supported observational data in the operational suite.	Mr S. Waters	1994
19	Subjective assessment of the 'Ambiguity Removal Confidence' for scatterometer winds derived from ERS-1	Mr S. Waters	1994
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